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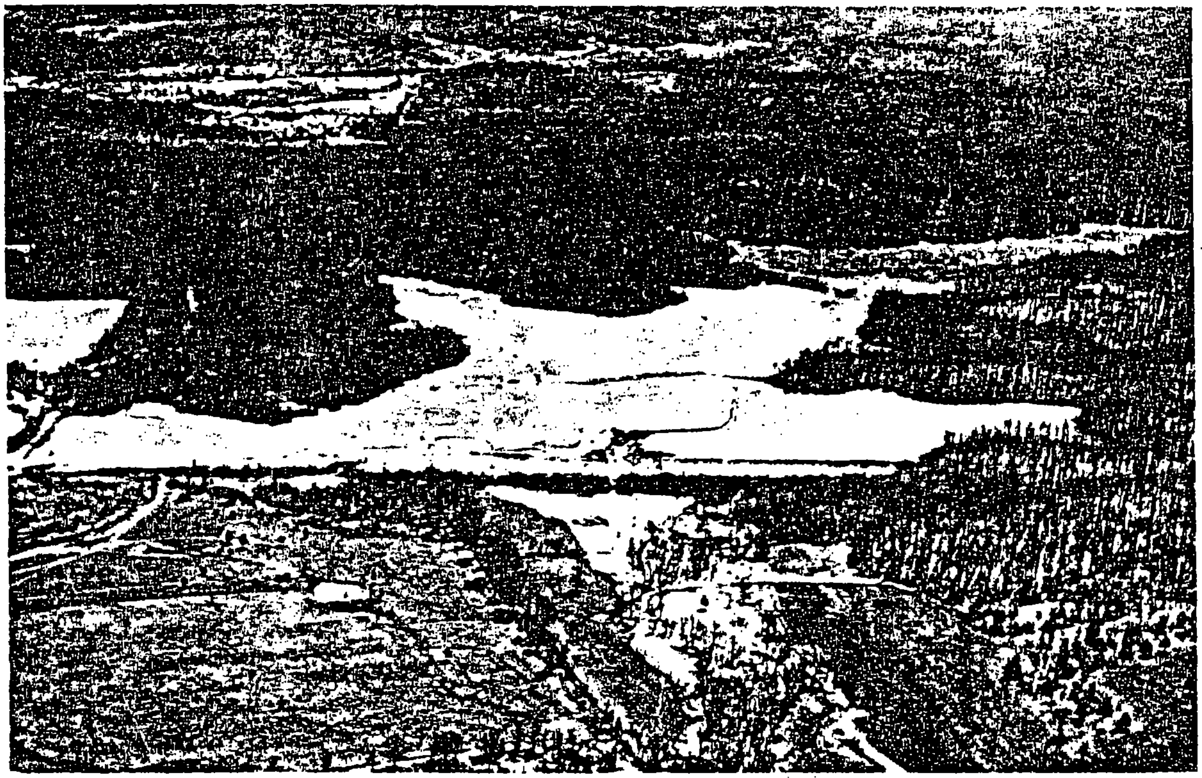
THE EFFECTS OF LEAD MINE TAILINGS ON THE WATER QUALITY OF SALINE CREEK AND THE LITTLE ST. FRANCIS RIVER, MADISON COUNTY, MISSOURI



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1980

Missouri Department of Conservation

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FOREWORD

This study was initiated to evaluate the effects of sediment discharged from a lead mine tailings pond during March 1977 on the water quality of Saline Creek and the Little St. Francis River in Madison County, Missouri. The objective was to evaluate these effects by determining the extent and duration of damage to the invertebrate communities of these streams for use as legal evidence to obtain relief from this pollution under Missouri's Clean Water Law.

Financial aid for this study was provided by the Missouri Department of Conservation (Project S-1-R-28, Study W-11) and Design for Conservation funds. This publication is a verbatim copy of the final report required by the Department. Copies are available from the Missouri Department of Conservation, Fish and Wildlife Research Center, 1110 College Avenue, Columbia, Missouri 65201.

The cover photograph is an aerial view of the tailings pond and the immediate downstream area following the collapse of the dam.

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ABSTRACT

A dam impounding a 40 acre lead mine tailings pond in Madison County, Missouri collapsed on March 28, 1977, after a heavy rain, allowing water and tailings to flow into Toler Creek, a wet-weather stream. The mixture continued down Toler Creek, flowed into Saline Creek, and ultimately entered the Little St. Francis River. The effects of these tailings upon the water quality of the latter two streams were assessed by comparing macroinvertebrate communities from two unaffected and three affected sites. Sixty samples of water and benthic invertebrates were collected from these sites during the study which ran from March 1977 and March 1978. The extent and duration of damage to these streams were determined by comparing the density, number of pollution sensitive mayfly and stonefly taxa, number of total taxa, and the diversity of the benthos communities between affected and unaffected sites.

The water quality of Saline Creek downstream from Toler Creek was adversely affected throughout the study. Damage to the Little St. Francis River was not as severe and confined to a reduction of pollution sensitive mayfly and stonefly taxa.

Although increased sediment was the most obvious cause of the poorer water quality in these streams, heavy metal contamination and/or another unidentified pollution source(s) may have contributed to the problem. No dead fish were observed during this study. However, high stream flow and extreme turbidity resulting from heavy rains and tailings may have masked a fish kill and prevented its detection.

INTRODUCTION

A dam impounding a 40 acre tailings pond owned by NL Industries collapsed on March 28, 1977, following a heavy rainfall, causing water and tailings to be discharged into Toler Creek, a small wet-weather stream. The mixture of tailings and water continued down Toler Creek, flowed into Saline Creek, and ultimately entered the Little St. Francis River (Fig. 1). Turbidity was increased in the affected areas of both streams, however, it was less noticeable in the Little St. Francis. Distressed or dead fish were not observed in either stream following the collapse, however, extreme turbidity and high water prevented a thorough search of the affected areas.

Several hundred acres of agricultural bottom lands were inundated by the mixture which resulted in the deposition of more than a foot of tailings in some locations. The deposited sediment drastically reduced or eliminated the crop production value of these lands.

Damage to the benthic macroinvertebrate communities in Saline Creek and the Little St. Francis River was determined by evaluating the benthic invertebrate communities inhabiting affected and unaffected areas. Since most benthic organisms are relatively immobile and cannot quickly avoid harmful changes, their presence, absence, or abundance reflects environmental conditions of the recent past (Chandler 1970). Population structure of these invertebrate communities also provided a measure of water quality conditions since invertebrates have different degrees of pollution tolerance (Gaufin 1958). Therefore, the severity and duration of damage at affected stations were determined by measuring the density, diversity, and composition of benthic invertebrate communities and comparing these characteristics with unaffected, upstream communities.

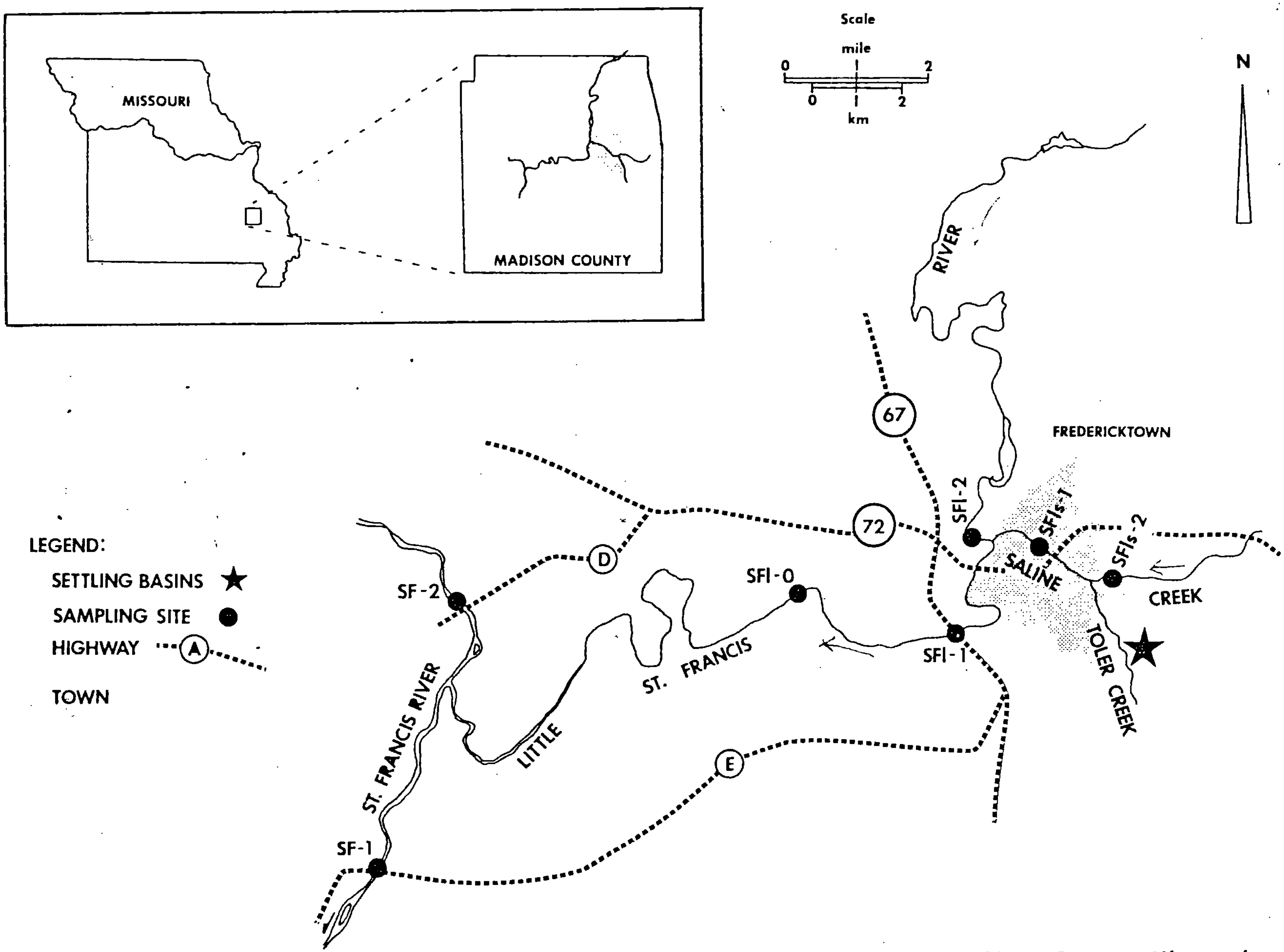

Figure 1. Sampling stations on Saline Creek and the Little St. Francis River, Madison County, Missouri, 1977-78.

DESCRIPTION OF THE STUDY AREA

Saline Creek and the Little St. Francis River flow through the geographic province of the Ozark Highlands known as the St. Francois Knob and Basin region (Sauer 1920). Typically, igneous rock knobs rise above the weak limestone and shale basins like irregularly distributed mountains. The local relief in this area is the greatest in the state. Only two soil types are represented to any extent in this region, the crystalline rock soils and the Fredericktown group. The latter is the best residual soils of the Ozarks with almost every available acre being farmed. The first group has virtually no agricultural value. The dominant terrestrial vegetation in the study area in the oak-pine climax association (Collier 1955).

Saline Creek is a high gradient stream (34 feet per mile), originates northeast of Fredericktown, Missouri in Madison County and flows for about 7 miles before entering the Little St. Francis River (Fig. 1). Physical characteristics of Saline Creek are typical of Ozark streams. Unaffected portions are alkaline, clear, and have dissolved oxygen levels at or near saturation. Stream substrate consists of varying sized fragments of limestone and silica minerals. However, some of the minerals which comprise the substrate in streams which flow through the St. Francis Knob and Basin region are different than other streams in the Ozark Highlands. As in Mill Creek and Big River, Washington County (Duchrow 1978), silica fragments are in the form of Potosi druse instead of chert which is the typical form of silica in the Ozark Highlands. Potosi druse and chert greatly enhances the habitat available in a stream for benthic invertebrate production. Potosi druse and chert are fine textured, compact, irregularly shaped, and contain large quantities of silica. This makes the material very resistant to physical weathering and chemical breakdown (Sauer 1920). Since the druse fragments vary greatly in size and shape, they pack loosely producing large interstitial spaces. This greatly increases the habitat and allows large quantities of water to pass through the stream bed during dry periods (Clifford 1966). Diatoms are the dominant benthic flora found in the unaffected portions of Saline Creek.

Treated sewage effluent from Fredericktown's trickling filter plant enters Saline Creek downstream from the two sampling stations established on this stream. This treatment facility is more than 20 years old and considered to be overloaded. Because of superior operation, the effluent from this plant meets the effluent standards most of the time. Fredericktown has received a grant to upgrade this facility (Department of Natural Resources 1976).

The Little St. Francis River begins in St. Francois County southeast of Farmington, Missouri. It flows south for approximately 30 miles before entering the St. Francis River near Silver Mine (Fig. 1). Physical and chemical characteristics of the Little St. Francis are similar to those described for Saline Creek with the exception of discharge. According to Buehler (1940) and preliminary field data on file at the Water Resources Office, U.S. Geological Survey, Rolla, Missouri, discharge is slightly greater (average - 408 cubic feet per second, range 0.3 - 3,450 cubic feet per second between 1939-1962) and the gradient is not as steep (11 feet per mile) in the Little St. Francis River as in Saline Creek. In areas unaffected by pollution, diatoms are the dominant benthic flora.

Flow is maintained in the Little St. Francis River by the Fredericktown water supply lake which has a multiple outlet structure. The 158 acre lake is located about 1 1/2 miles upstream from its confluence with Saline Creek (Fig. 1). The only potential pollution discharge is the Fredericktown trickling filter plant which enters Saline Creek. Tremendous growths of filamentous algae were noted in the Little St. Francis River immediately below Saline Creek between May and July 1977. This growth made sampling more difficult and possibly caused dissolved oxygen fluctuations in the Little St. Francis River.

MATERIALS AND METHODS

Benthic macroinvertebrate samples were collected at two sites on Saline Creek and three on the Little St. Francis River (Fig. 1 and Table 1). The stations on Saline Creek were located above (SFls-2) and below (SFls-1) the mouth of Toler Creek. The stations on the Little St. Francis River were established above (SFl-2) and below the mouth of Saline Creek (SF-1), and further downstream near its mouth at SFl-0.

Invertebrate samples were collected bi-monthly between March and June 1977, monthly between July and September 1977, and once during November 1977 and March 1978. All samples were collected from permanent, stable riffle areas at each sampling site by disturbing the substrate with a three-pronged digging tool to a depth of 4 to 6 inches. Dislodged organisms were captured in a Turtox No. 105T33 heavy nylon bottom net (20 mesh per inch) placed immediately below the sample site. Between 8 to 12 square feet of riffle substrate were sampled during each collection at each station during the year.

Table 1. Benthic invertebrate and water sampling station locations on Saline Creek and the Little St. Francis River, 1977-1978.

Stream	Station	County	Legal Description	Landmarks
Saline Creek	SF1s-2	Madison	T33N R7E Sec. 9 SW ¼	About 200 yds upstream from abandoned railroad crossing of Madison County Route Z, above mouth of Toler Creek.
Saline Creek	SF1s-1	Madison	T33N R7E Sec. 8	First riffle downstream from N. Maple St. crossing below mouth of Toler Creek, above trickling filter plant.
Little St. Francis River	SF1-2	Madison	T33N R7E Sec. 7 NE ¼	First riffle upstream from mouth of Saline Creek, just downstream from the mouth of Village Creek.
Little St. Francis River	SF1-1	Madison	T33N R7E Sur. 3316 NE ¼	First riffle downstream from Hwy. 72 (Bus. 67) crossing; about ½ mile downstream from mouth of Saline Creek.
Little St. Francis River	SF1-0	Madison	T33N R6E Sur. 1872 NW ¼	First riffle downstream from low water crossing, about 5 miles downstream from mouth of Saline Creek.
St. Francis River*	SF-2	Madison	T33N R5E Sec. 12 SE ¼	About 50 yds upstream from Madison County Route D crossing.
St. Francis River*	SF-1	Madison	T33N R5E Sec. 35 SE ¼	About 50 yds downstream from Madison County Route E crossing.

* indicates water sampling station only

Debris and invertebrates collected in the bottom net were placed into two screened pans for washing. The upper pan had hardware cloth screen (2 mesh per inch) and the lower pan a stainless steel wire screen (50 mesh per inch). Debris remaining in the upper screen was checked for organisms and discarded. Organisms from the upper screened pan and all material from the lower screened pan were preserved in 10% formalin. Samples were transported to the laboratory where the preservative was changed to 70% ethanol.

Samples to be sorted were washed with water in a U.S. No. 35 Standard Seive to remove the ethanol. Most organisms were removed from the debris by the sugar flotation method described by Anderson (1959). Debris was also systematically hand sorted to insure removal of all invertebrates. Organisms were then preserved in 70% ethanol before identification.

Identification of invertebrates was accomplished using compound and binocular dissecting microscopes and the following references: Beck (1976); Borror and Delong (1971); Burks (1953); Curry (1958); de la Torre-Bueno (1937); Frison (1935, 1942); Grabau (1955); Hilsenhoff (1970, 1975); Johannsen (1934); Lewis (1974); Merritt and Cummins (1978); Peterson (1960, 1962); Ross (1944); Ross and Horsfall (1965); U. S. Environmental Protection Agency (1972); Usinger (1963); Ward and Whipple (1959); Wiggins (1977); and Williams (1954).

Benthic organisms were identified to the following taxonomic levels:

(1) Flatworms (Platyhelminthes), roundworms (Nematoda), and segmented worms (Annelida) were identified to class.
(2) True flies (Diptera) were identified to family or genus.
(3) Mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), naiades (Pelecypoda), snails (Gastropoda), crustaceans, and other organisms were identified to genus or species.

Duplicate water samples were collected at each invertebrate sampling station on Saline Creek and the Little St. Francis River throughout the survey. Water samples were also collected from the St. Francis River above and below the mouth of the Little St. Francis (Fig. 1 and Table 1) to monitor heavy metal concentrations. All samples were analyzed for specific conductance, pH and turbidity. Initially, heavy metal analyses for aluminum, cadmium, chromium, copper, iron, lead, manganese, nickel, zinc, and cobalt were conducted. Heavy metal analyses for lead, cadmium, copper, and zinc were continued on these samples to check for lethal concentrations of these elements. All analyses were done in accordance to procedures outlined in American Public Health Association (1971).

Invertebrate data collected at each station were examined qualitatively and quantitatively to determine the extent of damage to benthic communities in areas which received sediment from the tailings pond. This examination included comparing benthic invertebrate community characteristics such as the number of mayfly and stonefly taxa, total number of taxa, invertebrate sample density, and species diversity index values between samples collected at stations above and below the inflow of sediment on each stream for the same date. Coefficients of similarity for invertebrate samples helped to determine the severity and duration of damage in each study stream.

Other methods of detecting damage at stations which received sediment included the presence, absence, or abundance of indicator organisms other than mayflies and stoneflies and the comparison of sample benthic community characteristics to criteria established for unpolluted Missouri streams (Table 2). The number of mayfly and stonefly taxa, total number of taxa, and diversity of organisms collected at each station were pooled throughout the year and also compared to criteria established for unpolluted Missouri streams (Table 2). These latter comparisons were made to see if the invertebrate communities at stations which received sediment were significantly reduced throughout the study.

Table 2. Water quality criteria for unpolluted Missouri streams.[1]

	Individual Sample		Pooled (Annual)		
Water quality designation	Species diversity index value	No. of mayfly and stonefly taxa	Species diversity index value	No. of mayfly and stonefly taxa	Total taxa
Unpolluted	>3.9	>9	>6.9	>21	>56
Moderately Polluted	2.2-3.9	5-9	3.8-6.9	10-21	31-56
Polluted	<2.2	<5	<3.8	<10	<31

1-Based on work done in Missouri by Kuester (1964), Duchrow (1974, 1976a, 1976b, and 1977), Ryck (1974, 1976), and Dieffenbach and Ryck (1976) and regression analysis of 895 samples.

Benthic community characteristics were determined in the following manner. The number of mayfly and stonefly taxa and total taxa were simple counts of taxa in each sample. Annual characteristics for each sampling station were determined by the sum of different taxa collected at that station for the year. Density was expressed simply as the number of organisms per unit area for each sample collected at a station. Species diversity index values (d) were calculated for each collection date and annually for each station using the equation derived by Margalef (1957) and discussed in detail by Wilhm (1967) and the U.S. Environmental Protection Agency (1973):

$$d = \frac{s-1}{\log_e N}$$

Where s equals the number of taxa and N the total number of organisms in the sample. In Missouri streams, diversity values have ranged from 0.0 (low) to 10.0 (high). Annual species diversity index values were calculated for each station using pooled values for s and N at these stations.

Coefficients of similarity (C) described by Burlington (1962) were used to determine the degree of damage caused by sediment and heavy metals discharged from the tailings pond. Coefficients comparing the invertebrate communities at two stations on the same date were calculated from the equation:

$$C = \frac{200W}{a + b}$$

Where a is the sum of prominence values for each type of organism at station 1; b is the sum of prominence values for each type organism at station 2; and W is the sum of the prominence values for each type of organism the two stations had in common. A prominence value for each type of organism at any station was calculated by multiplying the square root of the organisms frequency of occurrence (the percent of stations at which the organism occurs) by its density (numbers per square foot) at that station. Coefficients of similarity greater than 50 are considered high, indicating that the stations being compared have similar invertebrate communities. Values less than 50 indicate decreasing similarity in the invertebrate communities being compared (Duchrow 1976a, 1976b, and 1977; Dieffenbach and Ryck 1976).

Invertebrate taxa other than mayflies and stoneflies which are pollution sensitive and typically found in unpolluted Missouri streams (Gaufin 1958; Roback 1962; Kuester 1964; Duchrow 1974, 1976a, 1976b, and 1977; Ryck 1974, 1976; Dieffenbach and Ryck 1976)were also used as further evidence of degradation in the affected streams.

RESULTS AND DISCUSSION

A total of 126 invertebrate taxa were identified in samples collected from Saline Creek and the Little St. Francis River during 1977-78. This number is exclusive of 12 genera of midge larvae (Family Chironomidae) also identified in a portion of these samples. A taxonomic breakdown of these taxa by station is given in Table 3 and annual benthic invertebrate community characteristics are shown in Table 4.

Table 4. Annual benthic invertebrate community characteristics for stations on Saline Creek and the Little St. Francis River.

Station	Density (#/ft^2)	Number of total taxa	Number of mayfly and stonefly taxa	Species diversity index (d)
Saline Creek				
SFls-2 (control)	537	77	20	7.0
SFls-1	74	53	8	5.9
Little St. Francis				
SFl-2 (control)	215	76	23	7.5
SFl-1	420	69	16	6.3
SFl-0	282	80	20	7.6

Table 3. Taxonomic list, by station, of benthic invertebrates identified in samples collected from Saline Creek and the Little St. Francis River, 1977-78.

Classification[1]	SF1s-2	SF1s-1	SF1-2	SF1-1	SF1-0
Phylum: Arthropoda					
Class: Insecta					
Order: Plecoptera					
Family: Nemouridae					
Nemoura sp.	X				X
Family: Taeniopterygidae					
Brachyptera fasciata	X				
Taeniopteryx sp.			X		X
Family: Capniidae					
Allocapnia sp.	X		X	X	X
Family: Leuctridae					
Leuctra sp.	X				
Family: Perlidae					
Neoperla sp.	X	X	X	X	X
Perlesta placida	X	X	X	X	X
Acroneuria arida	X		X		
Family: Perlodidae					
Isogenus sp.	X				
Isoperla namata					X
I. mohri	X		X	X	X
I. bilineata/richardsoni	X				
Family: Chloroperlidae					
Chloroperla/Hastaperla	X				
Order: Ephemeroptera					
Family: Baetidae					
Baetis sp. (*levitans*)	X		X	X	X

Table 3. Continued

Classification[1]	SFls-2	SFls-1	SF1-2	SF1-1	SF1-0
Pseudocloeon sp.	X		X	X	X
Callibaetis sp.				X	
Family: Heptageniidae					
Stenonema pulchellum	X	X	X	X	X
S. nepotellum	X		X	X	X
S. vicarium					X
S. tripunctatum	X	X	X	X	X
Stenacron interpunctatum (gp.)		X	X	X	X
Heptagenia sp.			X		X
Family: Siphlonuridae					
Isonychia sp.	X	X	X	X	X
Family: Ephemerellidae					
Ephemerella bicolor (gp.)					X
E. needhami			X		
E. serrata (gp.)			X	X	
E. serratoides	X		X		X
Family: Ephemeridae					
Hexagenia sp.			X		
Family: Polymitarcyidae					
Ephoron sp.			X		
Family: Leptophlebiidae					
Choroterpes sp.			X		
Paraleptophlebia sp.			X	X	
Family: Tricorythodidae					
Tricorythodes sp.	X	X	X	X	X
Family: Caenidae					
Caenis sp.	X	X	X	X	X
Family: Baetiscidae					
Baetisca bajkovi					X
Order: Trichoptera					
Family: Hydropsychidae					
Cheumatopsyche sp.	X	X	X	X	X
Symphatopsyche bifida (gp.)			X		X
H. cuanis	X		X		X

Table 3. Continued

Classification[1]	SF1s-2	SF1s-1	SF1-2	SF1-1	SF1-0
H. betteni	X				
H. simulans	X				
Family: Rhyacophilidae					
Rhyacophila sp.	X	X			
Family: Polycentropodidae					
Nyctiophylax moestus	X				
Polycentropus sp.	X	X		X	X
Cyrnellus sp.	X				
Neureclipsis sp.					X
Family: Leptoceridae					
Oecetis sp.	X			X	X
Mystacides sp.				X	
Family: Helicopsychidae					
Helicopsyche sp.	X		X		X
Family: Philopotamidae					
Chimarra obscura	X	X	X	X	X
C. aterrima	X	X	X	X	X
Family: Hydroptilidae					
Oxyethira sp.		X			
Hydroptila sp.	X	X	X	X	X
Agraylea sp.	X	X		X	
Ochrotrichia sp.	X	X	X	X	X
Family: Glossosomatidae					
Agapetus sp.	X				
Order: Odonata					
Family: Calopterygidae					
Hetaerina sp.	X				X
Family: Coenagrionidae					
Enallagma sp. (*geminatum*)	X	X		X	X
Argia sedula/violacea	X	X			X
A. moesta			X	X	X

Table 3. Continued

Classification[1]	SF1s-2	SF1s-1	SF1-2	SF1-1	SF1-0
Family: Aeshnidae			X	X	
Boyeria vinosa	X				
Family: Libellulidae					
Erythemis simplicollis				X	
Family: Gomphidae		X	X	X	
Hagenins brevistylus	X				X
Lanthus sp.	X				
Order: Coleoptera					
Family: Haliplidae					
Peltodytes lengi		X	X	X	
Family: Elmidae					
Optioservus sandersoni	X	X	X	X	X
Stenelmis sp.	X	X	X	X	X
Dubiraphia sp.	X	X	X	X	X
Ancyronyx sp.				X	X
Family: Gyrinidae					
Dineutus sp.			X		X
Family: Dytiscidae	X				X
Hydaticis sp.					X
Hydroporus undulatus				X	
Deronectes/Oreodytes			X		
Cybister sp.			X		
Family: Psephenidae					
Psephenus herricki	X	X	X	X	X
Ectopria nervosa					X
Family: Hydrophilidae					
Berosus sp.	X	X	X	X	X
Enochrus sp.	X		X		
Tropisternus ellipticus	X		X		
Family: Dryopidae					
Helichus lithophilus	X	X	X		X
Family: Helodidae			X		

Table 3. Continued

Classification[1]	SF1s-2	SF1s-1	SF1-2	SF1-1	SF1-0
Order: Diptera					
Family: Chironomidae *	X	X	X	X	X
Sub-family: Tanypodinae					
Tribe: Pentaneurini					
Ablabesmyia sp.					
Arctopelopia/Conchapelopia					
Sub-family: Orthocladiinae					
Tribe: Corynoneurini					
Thienemanniella sp.					
Tribe: Orthocladinni/Metricnemini					
Trichocladius sp					
Cricotopus sp.					
Eukiefferiella sp.					
Orthocladius sp.					
Sub-family: Chironominae					
Tribe: Chironomini					
Endochironomus sp.					
Microtendipes sp.					
Parachironomus sp.					
Phaenopsectra sp.					
Polypedilium sp.					
Family: Simuliidae					
Simulium sp.	X	X	X	X	X
Family: Empididae	X	X	X	X	X
Family: Stratiomyidae	X		X		X
Family: Muscidae	X	X		X	X
Family: Tipulidae					
Erioptera sp.	X	X		X	X
Antocha sp.	X				X
Tipula sp.	X	X	X	X	X
Eriocera/Hexatoma	X	X	X		X
Limonia sp.	X				
Erioptera/Pseudolimnophila	X				

Table 3. Continued

Classification[1]	SFls-2	SFls-1	SFl-2	SFl-1	SFl-0
Family: Tabanidae					
Chrysops/Tabanus	X	X	X	X	X
Family: Rhagionidae					
Atherix variegata		X		X	X
Family: Ceratopogonidae					
Bezzia, Probezzia,...,	X	X	X	X	X
Forcipomyia sp.	X		X	X	X
Atrichopogon sp.			X		
Family: Ephydridae	X			X	
Family: Culicidae					
Anopheles sp.				X	X
Family: Psychodidae					
Psychoda sp.		X			
Order: Megaloptera					
Family: Corydalidae					
Corydalus cornutus	X	X	X	X	X
Nigronia serricornis	X	X		X	X
Family: Sialidae					
Sialis sp.		X	X		X
Order: Hemiptera					
Family: Mesoveliidae					
Mesovelia sp.				X	X
Family: Veliidae					
Velia sp.		X			
Rhagovelia sp.		X	X	X	X
Microvelia sp.	X	X	X	X	X
Family: Corixidae	X	X			
Family: Hebridae					
Hebrus sp.			X		

Table 3. Continued

Classification[1]	SFls-2	SFls-1	SFl-2	SFl-1	SFl-0
Family: Gerridae					
Rheumatobates sp.		X			
Trepobates sp.			X		X
Potamobates sp.				X	
Order: Lepidoptera					
Family: Pyralidae					
Paragyractis sp.					X
Family: Nepticulidae					
Nepticula sp.					X
MISCELLANEOUS GROUPS					
Phylum: Annelida					
Class: Oligochaeta	X	X	X	X	X
Class: Hirudinea				X	
Phylum: Arthropoda					
Class: Arachnoidea					
Order: Acari	X	X	X	X	X
Class: Crustacea					
Order: Isopoda					
Family: Asellidae					
Asellus sp.	X	X	X	X	X
Order: Amphipoda					
Family: Gammaridae					
Gammarus sp.		X		X	
Family: Talitridae					
Hyalella azteca sp.			X		
Order: Decapoda					
Orconectes sp.			X		
Phylum: Nematomorpha					
Order: Gordiida	X				X

Table 3. Continued

Classification[1]	SFls-2	SFls-1	SF1-2	SF1-1	SF1-0
Phylum: Platyhelminthes					
Family: Planariidae	X	X	X	X	X
Phylum: Nemata	X	X	X	X	X
Phylum: Mollusca					
Class: Gastropoda					
Family: Physidae					
Physa sp.	X		X	X	X
Family: Ancylidae					
Ferrissia sp.			X	X	
Family: Lymnaeidae					
Lymnaea sp.			X		X
Family: Planorbidae	X		X	X	X
Class: Pelecypoda					
Family: Sphaeriidae	X	X		X	X
Family: Unionidae					
Strophitus u. undulatus				X	X

[1]Classification follows Merritt and Cummins (1978), Ward and Whipple (1959), and Wiggins (1977).

*Midges used for taxonomic breakdown of the Family Chironomidae were taken from a limited set of samples and do not represent total number of species collected from Saline Creek and the Little St. Francis River.

Statistical examination of these characteristics using an unpaired t-test showed significantly higher ($p \leq 0.05$) density, total taxa, mayfly and stonefly taxa, and diversity in Saline Creek at the control station (SFls-2) than at the station which was affected by the sediment (SFls-1). This indicates that the invertebrate community in Saline Creek was seriously affected by the discharge throughout the study. In the Little St. Francis River, significantly higher ($p \leq 0.05$) numbers of mayfly and stonefly taxa and diversity were observed at the control station (SF1-2) when compared to the station 1/2 mile below the mouth of Saline Creek (SF1-1). Density and total taxa were not significantly different at these two stations throughout the study. No significant difference ($p \geq 0.05$) was found in these four characteristics between the control (SF1-2) station and station SF1-0, located 5 miles downstream from the mouth of Saline Creek.

These comparisons revealed that the severity and extent of damage to the benthic invertebrates in these two streams were different. For this reason, a detailed discussion of the results for each stream is given separately.

Saline Creek

Three days after the break, turbidity in Saline Creek at SFls-1, downstream from the mouth of Toler Creek was 125 Jackson Turbidity Units and was significantly higher ($p \leq 0.01$) than the turbidity at the control station (SFls-2). Turbidity in water samples collected at the same time near the break was 6,500 Jackson Turbidity Units. Highest turbidity values measured during the study were 22,800 Jackson Turbidity Units near the tailings pond on the day of the collapse. Turbidity values between the control and affected stations on

Saline Creek were not significantly different ($p \geq 0.05$) for the remainder of the study. Dead fish were not observed in Saline Creek. Apparently, acute concentrations of sediment and/or heavy metals did not occur in Saline Creek. Suspended sediment concentrations in Saline Creek, as indicated by turbidity values, did not approach the concentrations (75,000 Jackson Turbidity Units) which caused a fish kill in Mill Creek in a similar incident in 1975 (Duchrow 1978).

Chemical analyses, for ten metals including cadmium, copper, lead, and zinc in water collected at the affected station (SFls-1), revealed that 3 days after the break there were no acutely toxic concentrations of these dissolved metals.

There was a statistically significant reduction in the benthic invertebrates throughout the study in the affected portion of Saline Creek. The significant difference between the community characteristics shown in Table 4 are the basis for this conclusion. Further evidence which supports these conclusions are shown in Figs. 2 and 3. These figures graphically illustrate, on a sample basis, the reduction in invertebrate density, total taxa, mayfly and stonefly taxa, and species diversity which occurred at the affected station (SFls-1) throughout the study. Coefficients of similarity comparing the invertebrate communities at the two sampling sites showed dissimilar communities through 234 days after the break (Fig. 4). All comparisons document the degrading effects of the tailings on the invertebrate community in Saline Creek downstream from Toler Creek. Damage on the species level similar to that which occurred in Mill Creek following the discharge of barite tailings (Duchrow 1978) was not

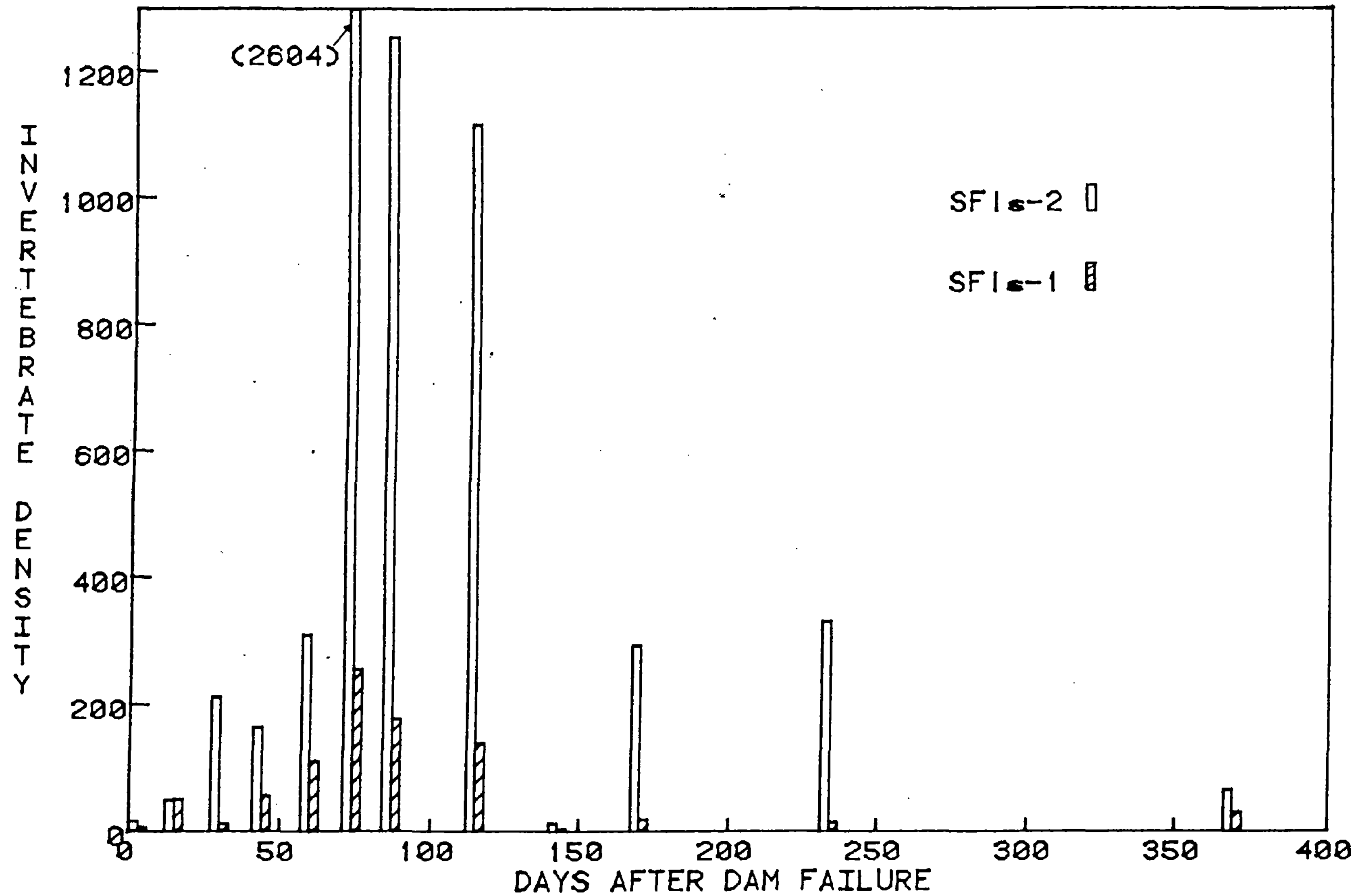

FIGURE 2. INVERTEBRATE DENSITY FOR STATIONS ON SALINE CREEK. 1977-78.

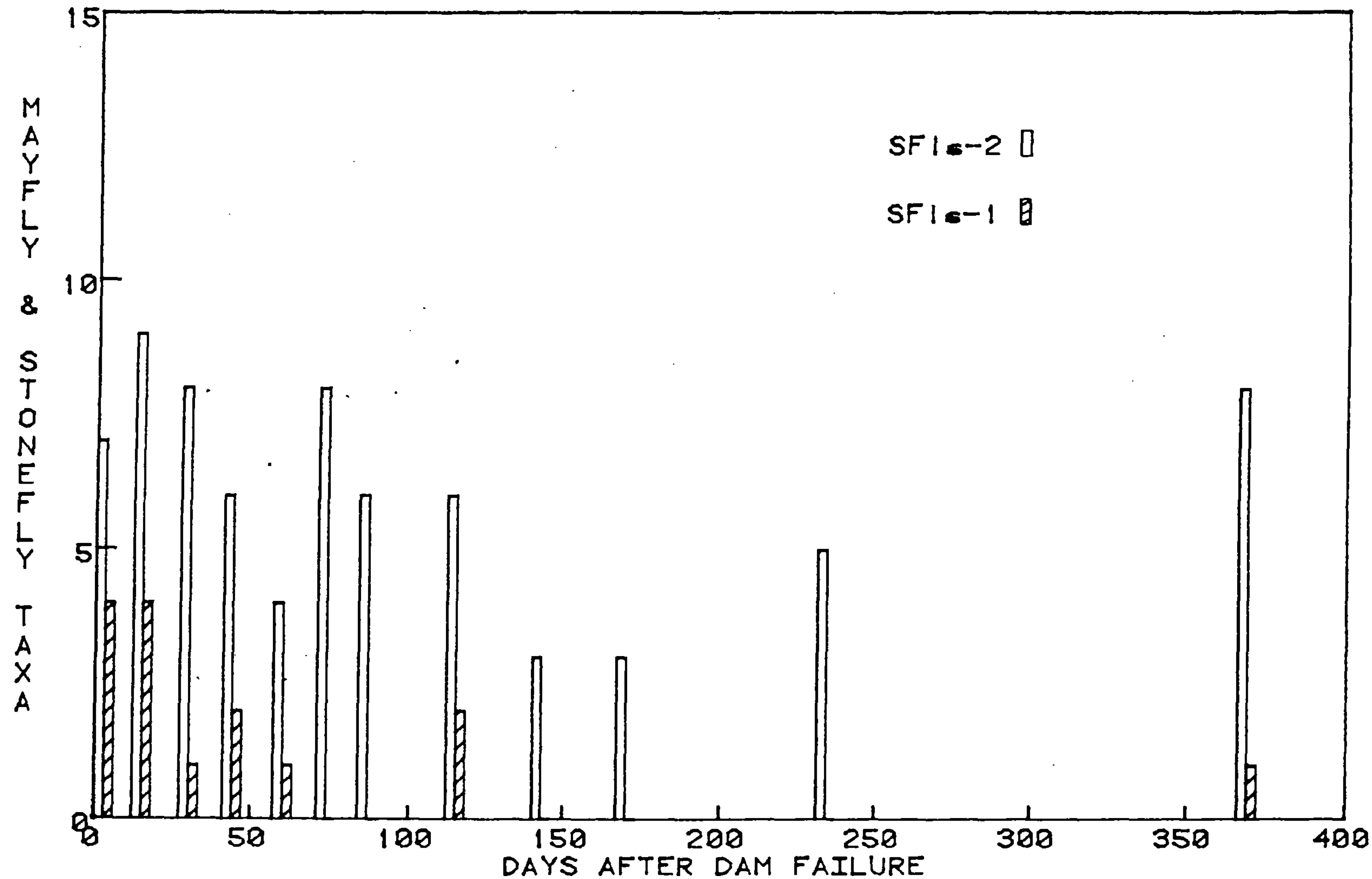

FIGURE 3A. MAYFLY AND STONEFLY TAXA FOR STATIONS ON SALINE CREEK. 77-78.

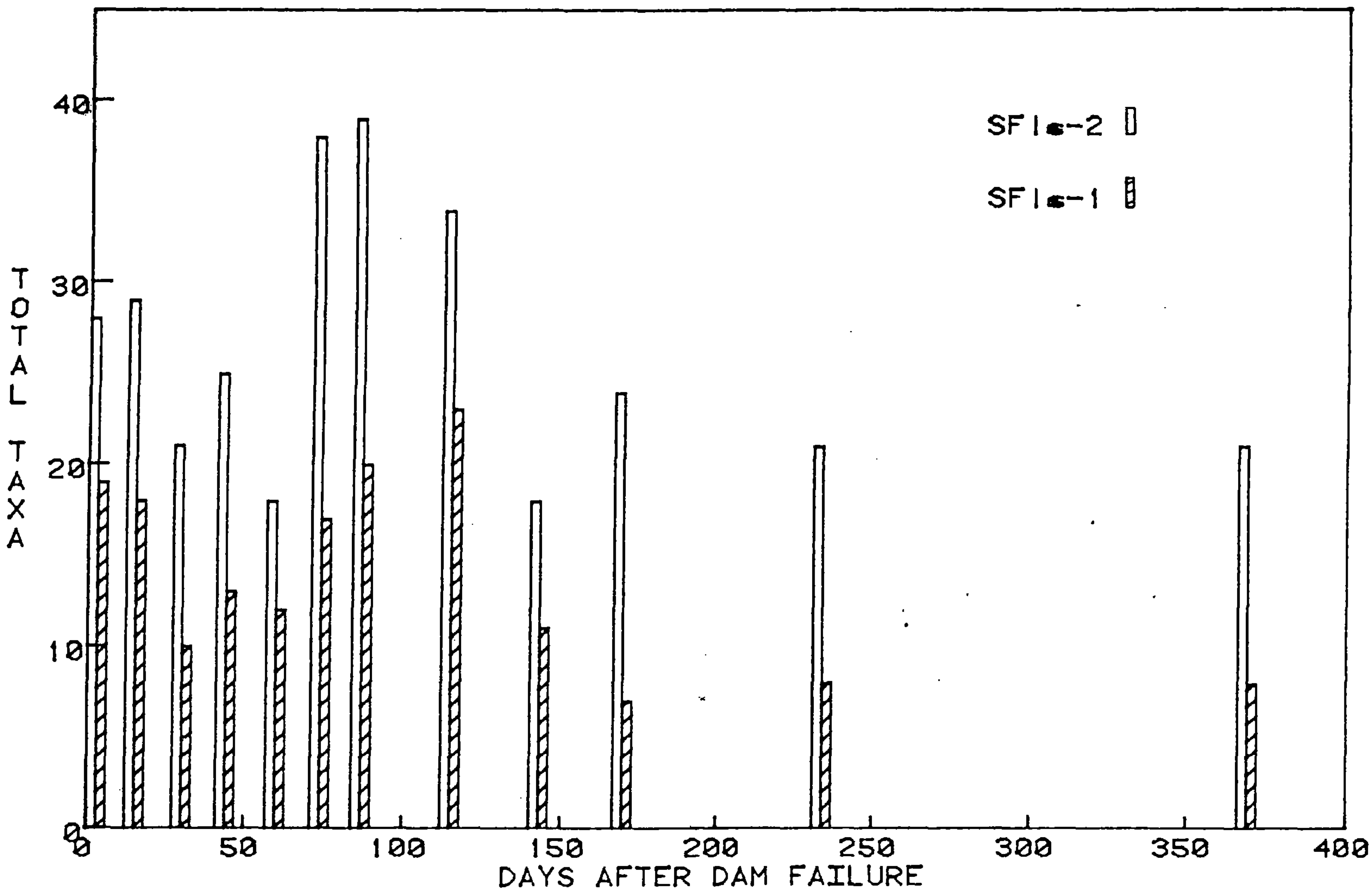

FIGURE 3B. TOTAL TAXA FOR STATIONS ON SALINE CREEK. 1977-78.

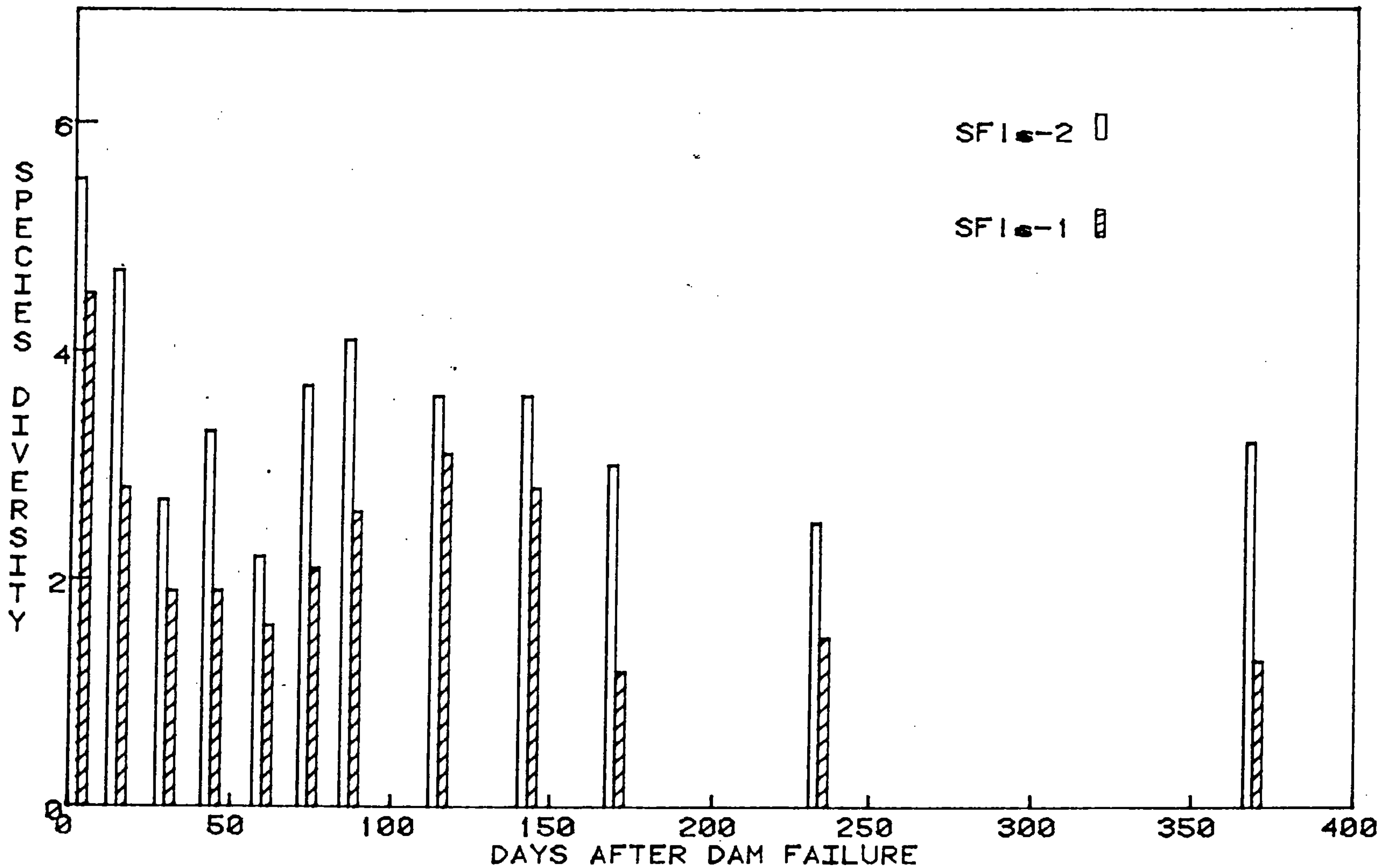

FIGURE 3C. SPECIES DIVERSITY VALUES FOR STATIONS ON SALINE CREEK. 77-78.

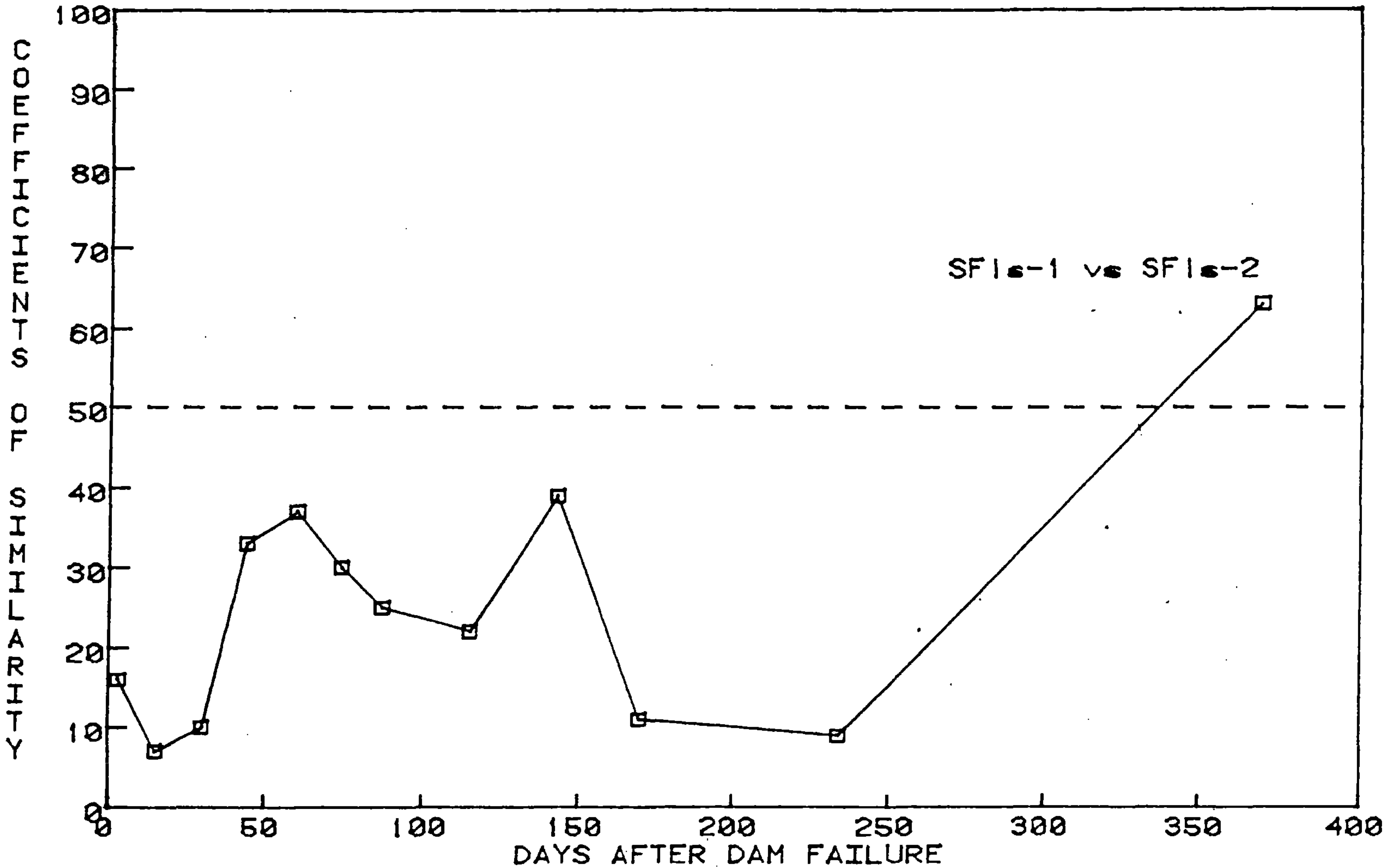

FIGURE 4. COEFFICIENTS OF SIMILARITY FOR SALINE CREEK. 1977-78.

indicated by the benthos data collected from Saline Creek. The damaging effects from the tailings in this study appeared to be equally devastating to all groups or species of benthic invertebrates. The specific cause of this degradation is not as easily determined. As mentioned previously, a significant amount of sediment entered Saline Creek initially from the break, however, the break was repaired and the discharge of sediment did not persist.

Water samples collected throughout the study at both stations on Saline Creek showed concentrations of cadmium, copper, lead, and zinc to be quite low (Fig. 5). These concentrations never approached the acute toxicity levels reported by the U.S. Environmental Protection Agency (1976). Safe limit concentrations for the protection of aquatic organisms set by the Missouri Department of Natural Resources (1977) are given for each metal in Figure 5. These limits closely parallel limits listed in E.P.A. (1976). Although cadmium, lead, and zinc concentrations were always below these safe concentration limits, copper exceeded the safe limit twice (Fig. 5). Decreases in invertebrate community similarity were also noted during these two time periods (Fig. 4). This suggests a possible relationship between the deterioration in the invertebrate community downstream from Toler Creek and copper concentrations, however these increases are not believed to be the primary cause of the continued degradation noted through the 234 days following the dam failure.

This study has adequately documented the pollution of Saline Creek by the tailings and the degradation which occurred in the invertebrate community in affected portions of Saline Creek, but the exact cause of deterioration was not determined.

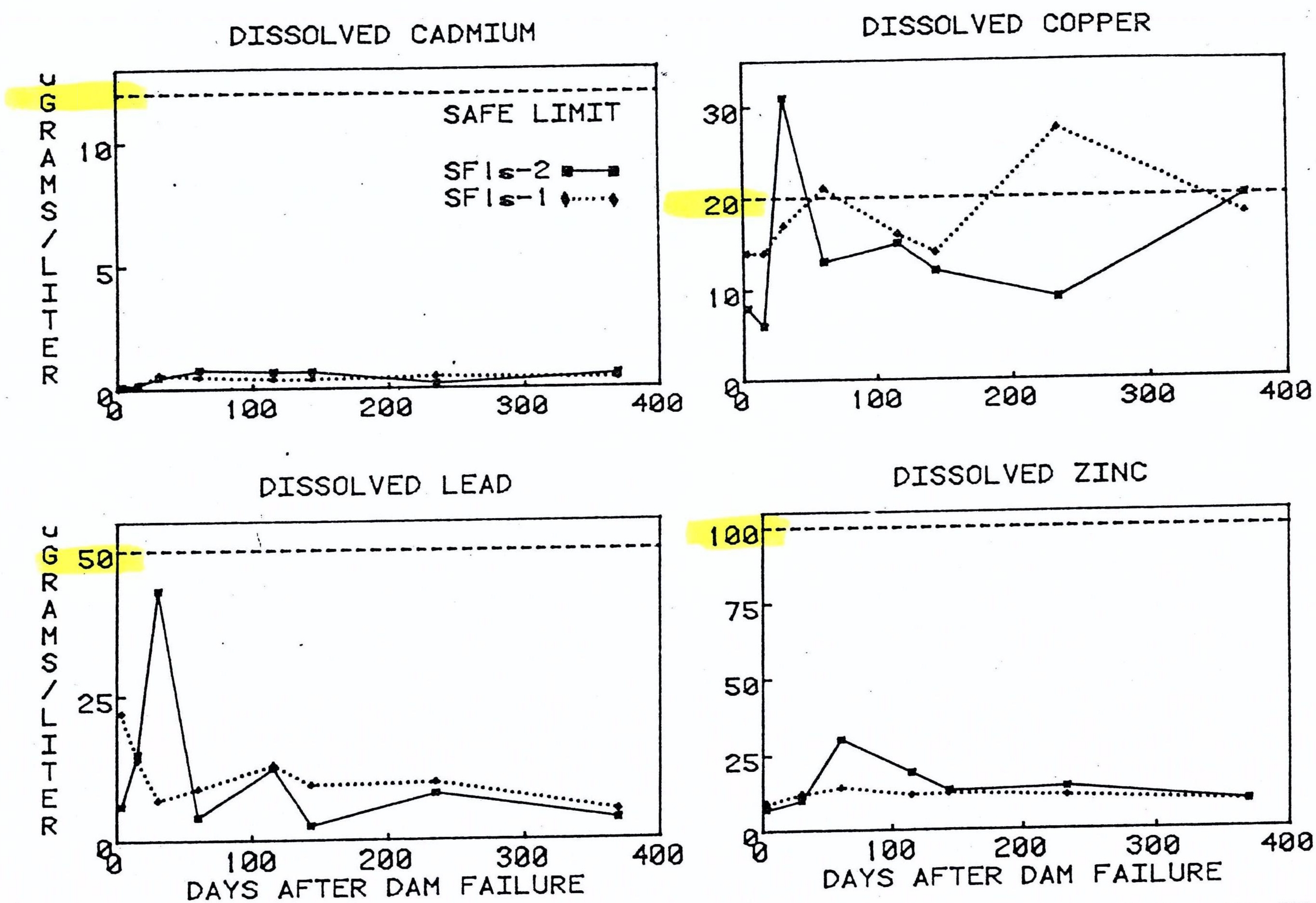

FIGURE 5. CADMIUM, COPPER, LEAD, AND ZINC LEVELS FOR SALINE CREEK, 77-78

The study was terminated after 369 days with all benthic invertebrate community characteristics indicating continuing degradation downstream from Toler Creek (Figs. 2-3). The coefficient of similarity for that date, however, indicated similarity to the unaffected station (SFls-2). No explanation is available for this occurrence.

Invertebrate samples collected during March 1979, about 2 years after the discharge of sediment, showed a reduced, dissimilar (C=22) invertebrate community still present in affected reaches of Saline Creek when compared to the upstream, control community. Community characteristics for these samples are as follow:

Station	Density (#/ft^2)	Number of total taxa	Number of mayfly and stonefly taxa	Species diversity index (d)
SFls-2 (above)	162	32	10	4.3
SFls-1 (below)	20	15	3	2.7

It is difficult to believe that the apparent continued degradation of the invertebrate community noted in Saline Creek in 1979, downstream from Toler Creek, is the result of a one time catastrophe 2 years earlier. Either undiscovered elements in the sediment are causing the problem or other pollutants are entering Saline Creek and to date remain undetected. In either case, further investigation into this problem is warranted.

Little St. Francis River

Three days after the dam break, turbidity in the Little St. Francis River at SF1-1 (Fig. 1), downstream from Saline Creek, was significantly higher ($p \leq 0.01$) than the control station (SF1-2). Actual turbidity in the water samples collected at SF1-1 averaged 39.5 Jackson Turbidity Units. This was substantially less than the 125 units observed in Saline Creek at SF1s-1 on the same date. No differences ($p \geq 0.05$) were noted between these two stations on the Little St. Francis for the remainder of the study. Significant differences ($p \geq 0.05$) between the turbidity in the Little St. Francis at the control and station SF1-0, located 5 miles downstream from the mouth of Saline Creek, were not observed throughout the study. Dead fish were not found in the Little St. Francis River.

Examination of benthic invertebrate community characteristics from stations on the Little St. Francis (Table 4) showed a significant difference ($p \leq 0.05$) between the number of pollution sensitive mayfly and stonefly taxa and diversity at SF1-1 when compared to the other two stations. This indicates that some form of stress was affecting these groups. However, Figures 6 and 7 show that there was no consistent reduction in any of the characteristics at SF1-1 throughout the study like the reductions observed in Saline Creek at SF1s-1 (Figs. 2-3).

Coefficients of similarity comparing the benthos communities at the control station with those at the stations downstream from Saline Creek also reflect this inconsistency (Fig. 8). The fluctuations in coefficients indicating similar and dissimilar communities reveal no definite pattern and cannot be explained by the biological and chemical data collected from the Little St. Francis River.

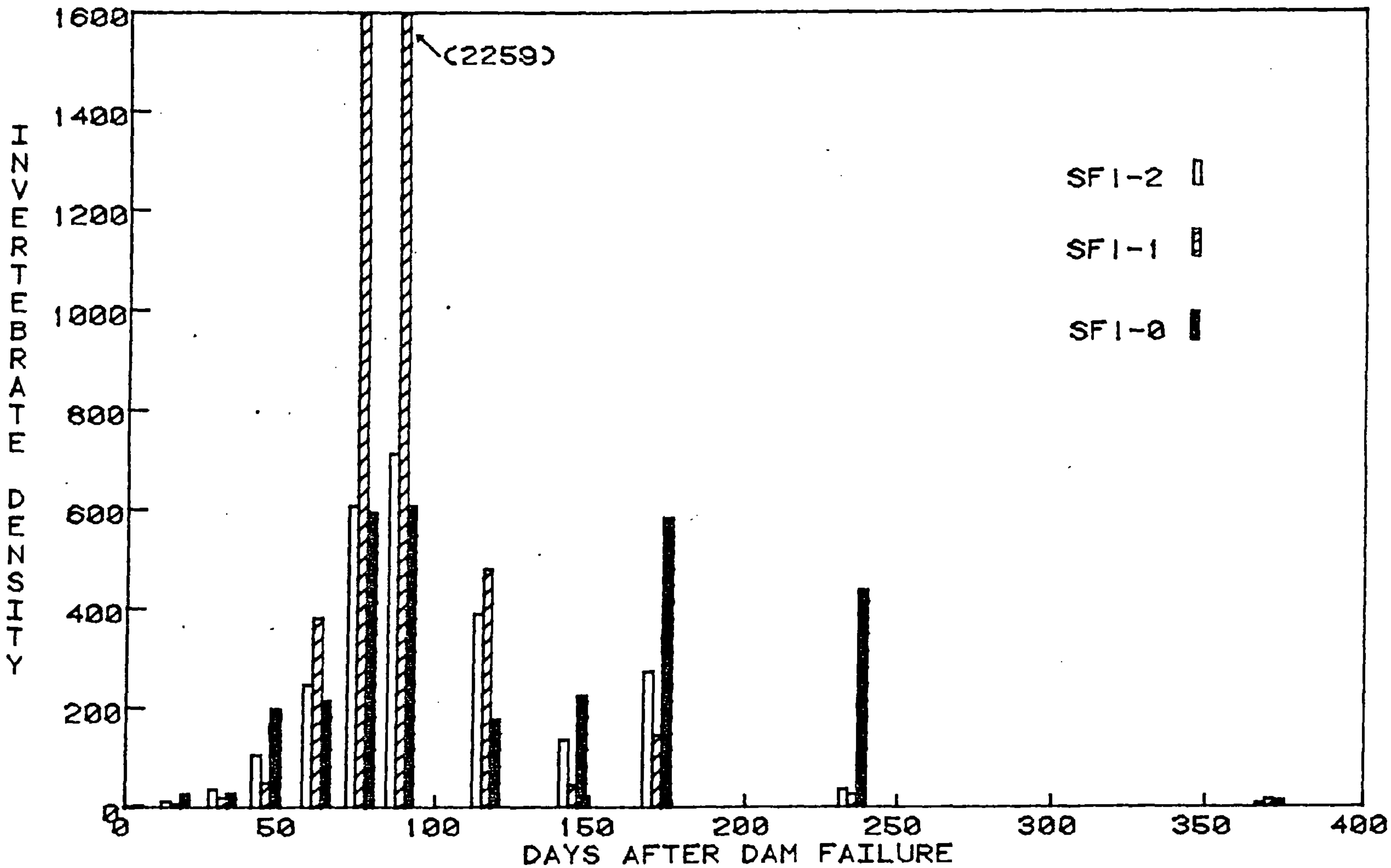

FIGURE 6. INVERTEBRATE DENSITY FOR THE LITTLE ST. FRANCIS RIVER. 1977-78

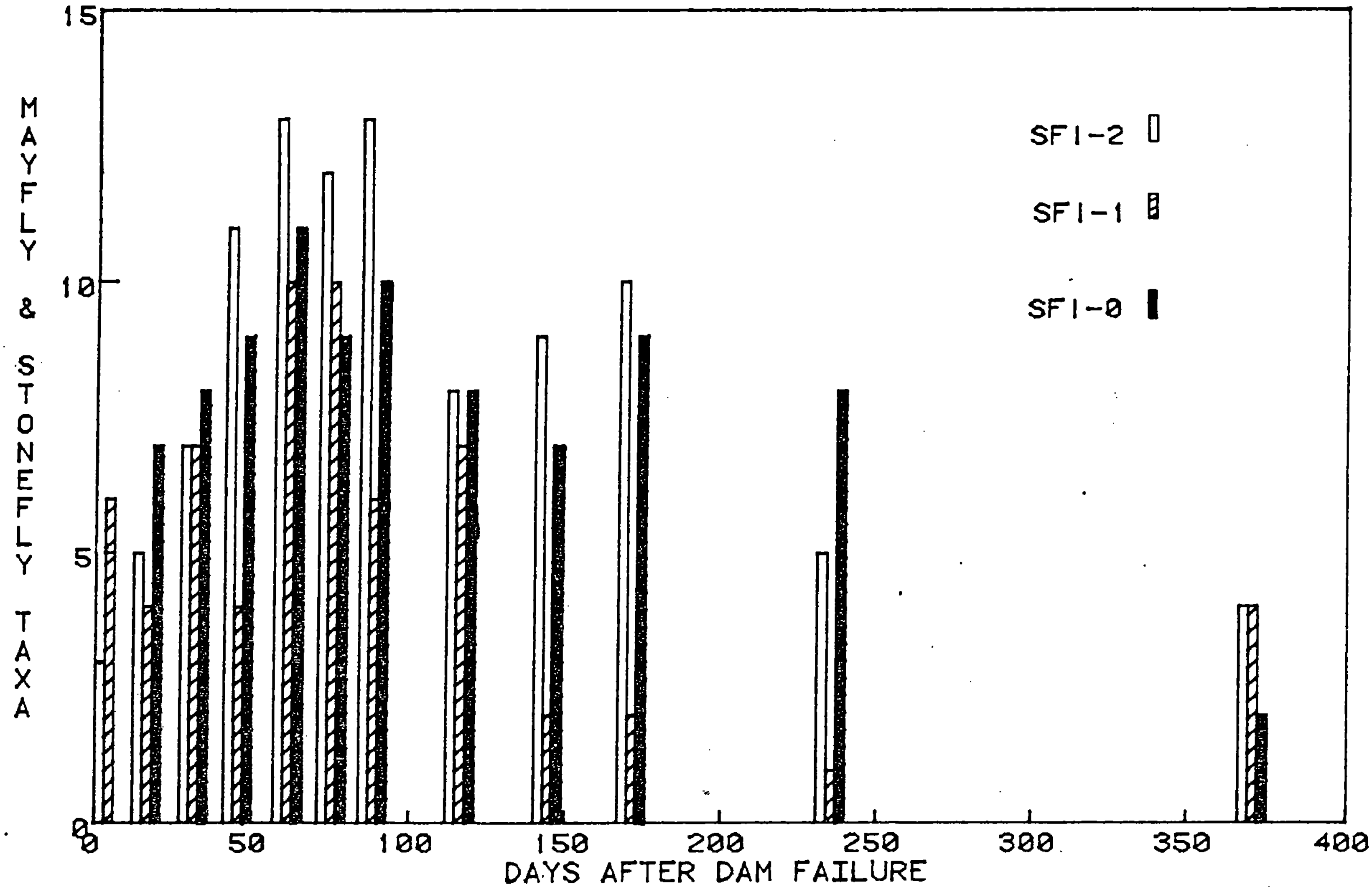

FIGURE 7A. MAYFLY AND STONEFLY TAXA FOR LITTLE ST. FRANCIS RIVER. 77-78.

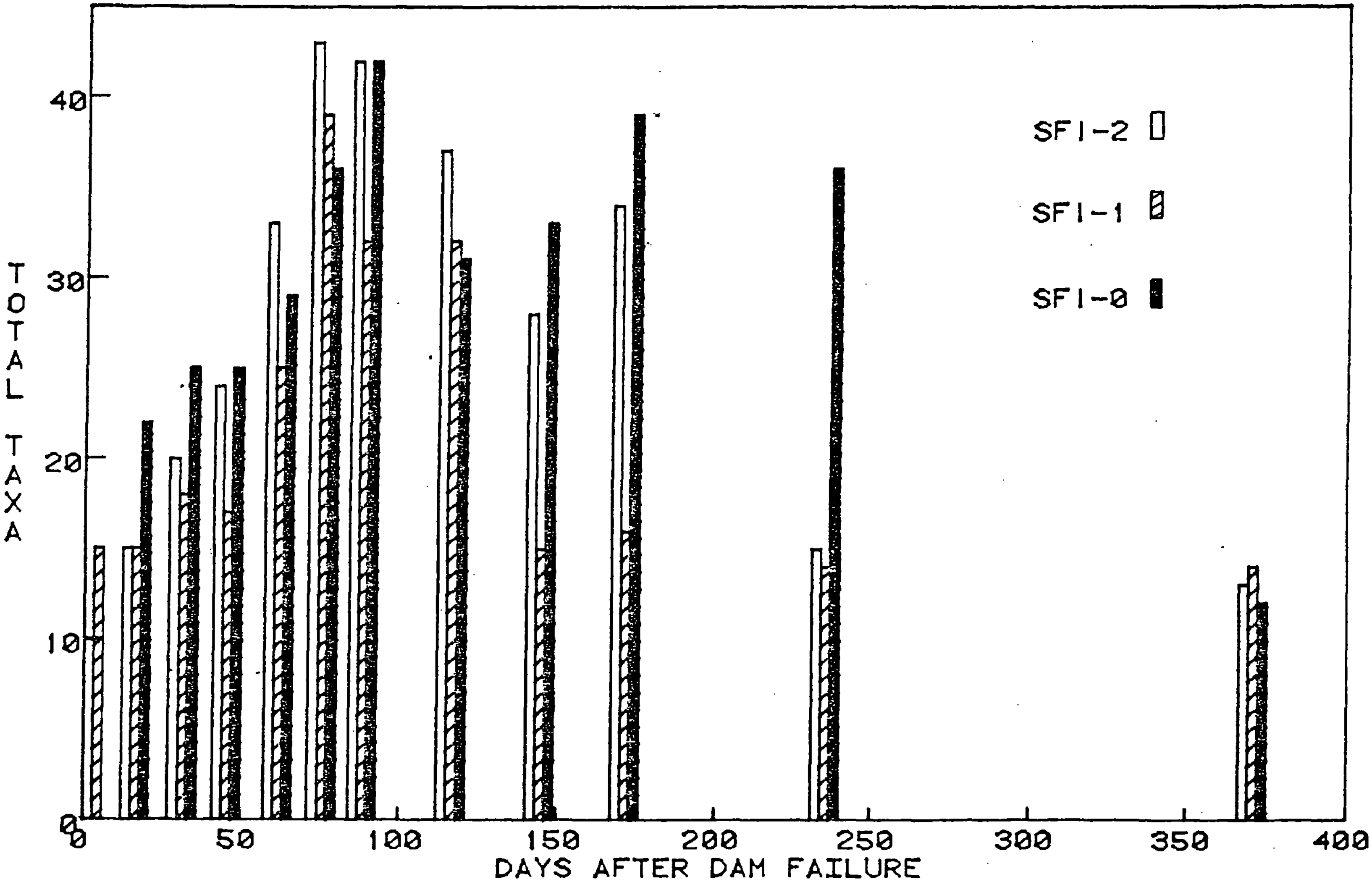

FIGURE 7B. TOTAL TAXA FOR THE LITTLE ST. FRANCIS RIVER. 1977-78.

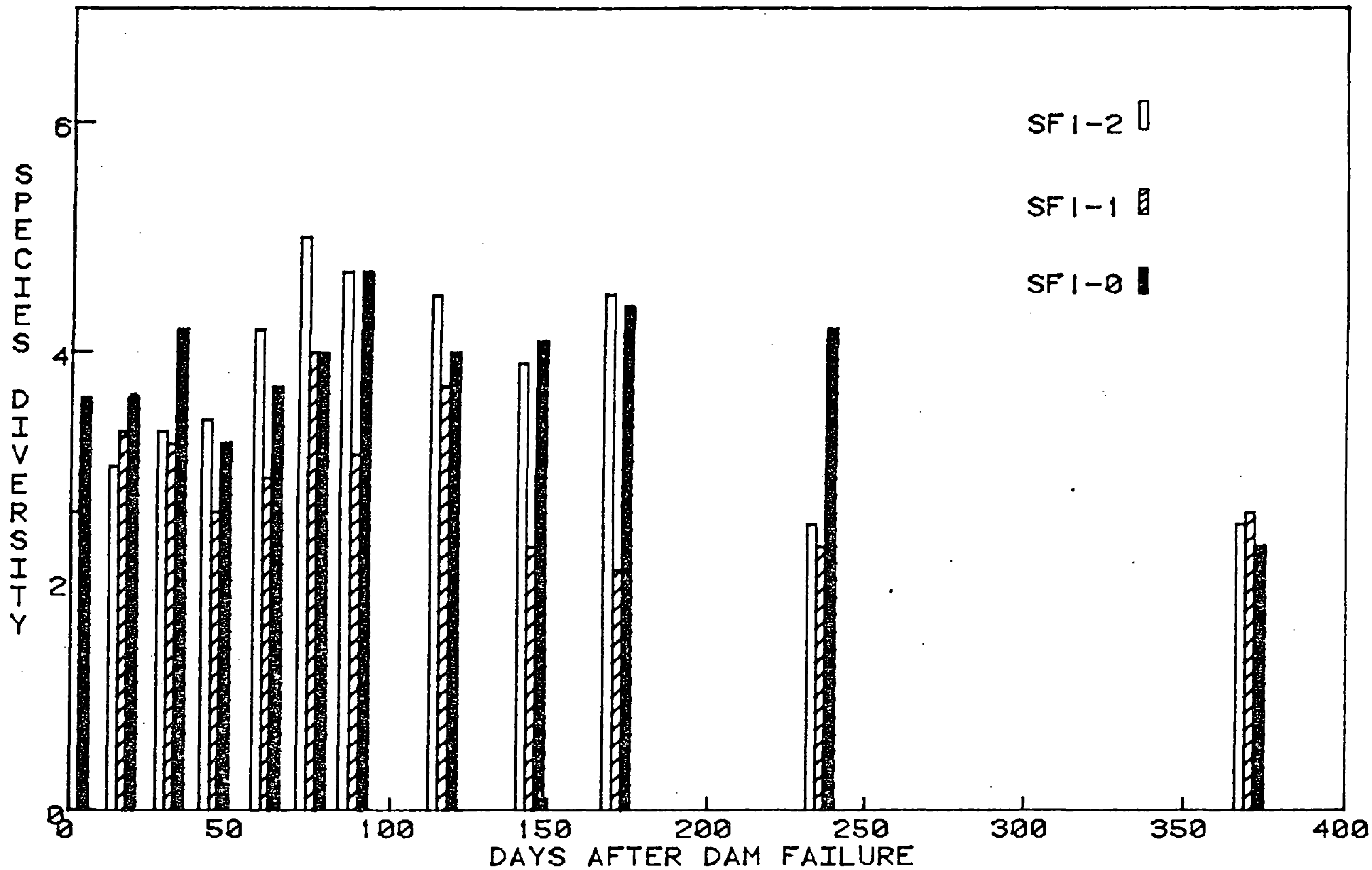

FIGURE 7C. SPECIES DIVERSITY VALUES FOR LITTLE ST. FRANCIS RIVER. 77-78.

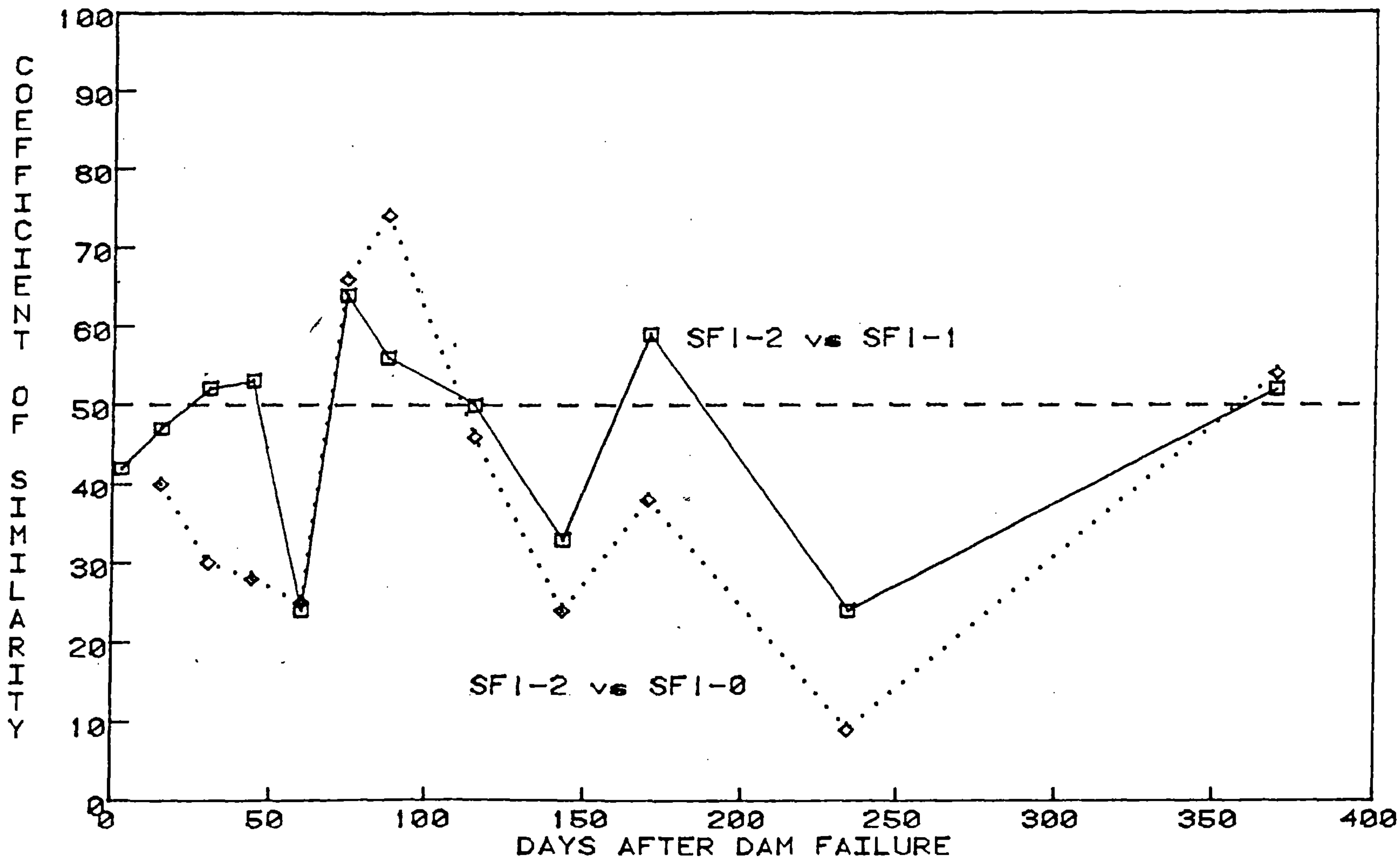

FIGURE 8. COEFFICIENTS OF SIMILARITY FOR LITTLE ST. FRANCIS RIVER. 77-78

Concentrations of cadmium, copper, lead and zinc in water samples collected at the three stations (Fig. 9) closely parallel the concentrations found in Saline Creek (Fig. 5). Acutely toxic levels for these metals were never approached and the safe limits for copper were only exceeded in three samples, downstream from the mouth of Saline Creek (Fig. 9). As in Saline Creek, the increased copper levels toward the end of the study were not believed to be the primary cause of the lower number of pollution sensitive mayfly and stonefly taxa collected from the Little St. Francis River at SF1-1. It is conceivable that a combination of stresses including sediment, sewage treatment plant effluent, and other possible unknown factors are responsible for the continued degradation noted in the Little St. Francis River.

St. Francis River

Water samples collected from the St. Francis River, above (SF-2) and below (SF-1) the mouth of the Little St. Francis River, showed no significant increases in heavy metal concentrations throughout the study.

CONCLUSIONS

The inflow of sediment from the NL Industries tailings pond adversely affected the water quality in downstream portions of Saline Creek. Reduced characteristics and dissimilar invertebrate communities (indicated by low coefficients of similarity) between the control and affected stations support this conclusion. No dead fish were observed. The damage to the invertebrates in Saline Creek was due primarily to the physical effects of the sediment, since heavy metal concentrations in water samples did not exceed safe limits to the protection of benthic fauna.

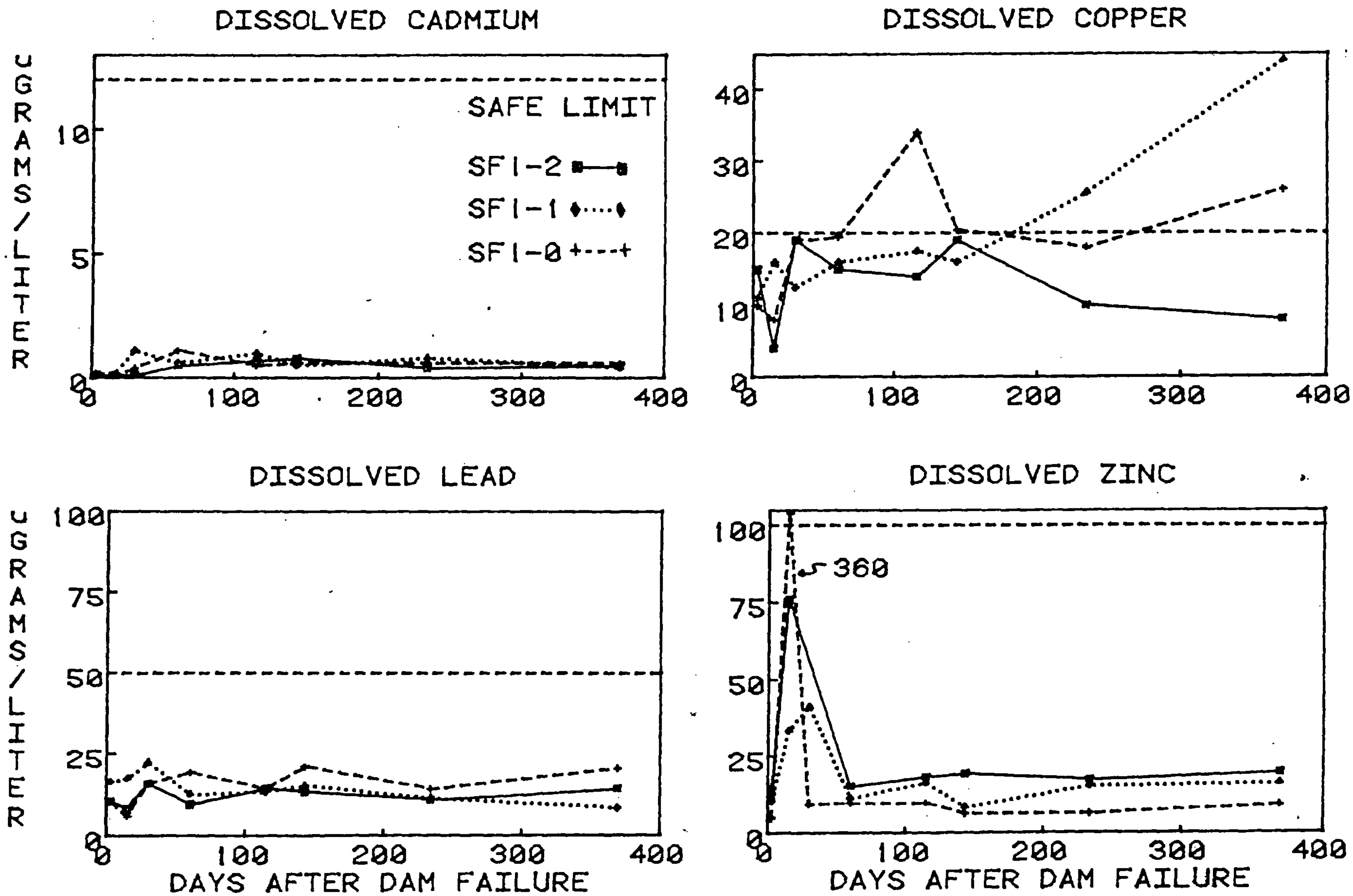

FIGURE 9. HEAVY METAL LEVELS FOR THE LITTLE ST. FRANCIS RIVER, 1977-78.

Water quality degradation appeared less severe downstream in the Little St. Francis River as evidenced by the reduction of only pollution sensitive mayfly and stonefly taxa. Accordingly, this damage was only evident within the first mile of stream below the mouth of Saline Creek. Degraded water quality was not evident further downstream on the Little St. Francis or St. Francis rivers. As in Saline Creek, the physical effects of the increased sediment was considered to be the primary reason for the damage observed in this stream. Further investigation would be necessary to determine if other possible sources of pollution could have aggravated this situation.

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